Report No. 215

MATERIALS APPLICATIONS BRANCH

CAUSES, PREVENTION AND CORRECTION OF SOLAR RADIATION INDUCED TEMPERATURE WARPAGE OF POLYETHYLENE SILHOUETTE RIFLE RANGE TARGETS

by

Leonard R. Weiner

22 July 1974

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MATERIALS ENGINEERING DIVISION

FELTMAN RESEARCH LABORATORY

Picatinny Arsenal, Dover, New Jersey

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Approved: Merrill Eig
MERRILL EIG
Actg Chief, Materials Applications Branch

Materials Engineering Division
Feltman Research Laboratory
Picatinny Arsenal
Dover, New Jersey

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--                   ***DTIC DOES NOT HAVE THIS ITEM***
-- 1 -  AD NUMBER: D405327
-- 5 -  CORPORATE AUTHOR: PICATINNY ARSENAL  DOVER N J
-- 6 -  UNCLASSIFIED TITLE:     CAUSES, PREVENTION AND CORRECTION OF SOLAR
--      RADIATION INDUCED TEMPERATURE WARPAGE OF POLYETHYLENE SILHOUETTE
--      RIFLE RANGE TARGETS.
--10 -  PERSONAL AUTHORS: WEINER,L.R. ;
--11 -  REPORT DATE:      JUL   , 1974
--12 -  PAGINATION: XXXXXX    MEDIA COST:  $  6.00
--14 -  REPORT NUMBER:    REPT. NO. 215
--20 -  REPORT CLASSIFICATION:  UNCLASSIFIED
--33 -  LIMITATION CODES:  1

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Acknowledgment

The author wishes to express his appreciation for the helpful discussions and assistance rendered by personnel of The Phillips Petroleum Company, RAI Research Corporation and Plaxall Inc.

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INTRODUCTION

A large proportion of plastics currently used in Army applications are exposed to the destructive influences of outdoor weather. Heat, cold, rain, sleet, ice, ultraviolet, infrared, ozone, oxygen, and a number of similar elements enter into a broad picture of gradual deterioration. Obvsiously, failure under environmental conditions is a critical factor limiting the use of polymeric compositions as engineering materials. Thus, determinations of these effects in advance is of a distinct economic advantage.

The running of a test program over the long outdoor exposure period normally required is an unsupportable burden for many suppliers and an unacceptable delay for the military user. On the other hand, reliance on limited initial material property and appearance specification requirements (Appendix A) entails the risk of failure shown in photographs (Figures 1 to 3) and described in detail (Appendix B). Other possible causative factors are improper design, material selection and process fabrication techniques.

Steps leading to the selection and design of the 80 mil high density (linear) polyethylene to replace kneeling silhouette (E type) fiberboard targets are well documented (Ref 1 to 4). Comments regarding current difficulties have been furnished by both the target developer (Appendix C) and the raw material producer (Appendix D).

Considering limitations of time and material furnished for this investigation, the most promising approach, at the time, was to determine material "equivalency" to "Marlex 6001" and the current extent of elevated temperature target warpage, its prevention, and corrective action to be applied to existing defective targets.

EXPERIMENTAL

Materials

Three silhouette plastics targets were used in this study. Two, (no identity as to manufacturer, lot, material etc.) were submitted by the Product Engineering Division, Rock Island Arsenal and presumably represent the field targets which warped at elevated temperatures. The other, obtained from Plaxall Inc. (target developer's molder) was represented to have been thermoformed from 100-110 mil pigmented Marlex 6001 linear high density polyethylene extruded sheet stock. Hereinafter, these targets will be referred to as "Field" and "Standard", respectively.

Procedures

One of the "Field" targets was submitted to Phillips Petroleum Co., the producer of Marlex 6001, for an independent evaluation (Appendix D). The other "Field" target was compared with the "Standard" for "Marlex 6001 equivalency". With the exception of thermal properties, standard tests were employed. For melting range, crystalline melt and freezing point determinations a Dupont 900 Differential Thermal Analyzer with attached Scanning Calorimeter was used. Penetration Point data was obtained with a Dupont 941 Thermomechanical Analyzer attached to the same basic instrument. In all cases the programmed heat rise was 5°C per minute. For freezing point, the samples were allowed to cool to ambient at an unspecified rate. For penetration point a 5 gm load applied to a penetration probe was supported by the test samples until the penetration point temperature was reached.

In addition, three 5" x 19.5" transversely sectioned samples of the "Field" target were subjected, in a sequence of experiments, to heat treatment at 260°F (127°C) for 2 hours and a variety of cooling procedures to determine:

a. The extent of warpage at elevated temperature.

b. The means for elimination of warpage.

c. Verification of the proper corrective action.

Due to lack of "Standard" material no warpage comparisons have been made in this study. Free movement and restraint fixtures used in these experiments are as shown in Figures 4 and 5. Warpage is defined in this series of experiments as the distance in inches of the maximum point of departure of the target from its original horizontal plane. This point occurred at the longitudinal center line of the target.

TEST RESULTS AND DISCUSSION

Material "Equivalency"

Based on Melt Index and Density the polyethylene used to form the "Field" target appears to be "equal" to the "Standard" Marlex 6001 (Table 1 and Appendix I). Since the properties mentioned above were the only ones specified on the piece part drawing (Appendix A), the "Field" target was accepted as the "equal" of the "Standard". However, a further comparison shows a significant difference in certain properties (Table 1) which could

effect end use performance. Therefore, the material used in the "Field" target cannot be considered the equal of the "Standard".

Since the "Field" target material has a lower intrinsic viscosity (average molecular weight $\bar{M}_W$) it would have a lower flexural modulus (stiffness) than the "Standard" at equivalent temperatures. An example of this phenomenon can be seen in Appendix E. Here, Marlex 5000 (lower $\bar{M}_W$) is compared with the "Standard" for flexural moduls (stiffness) over the climatic temperature range. The higher ash content (pigment) of the "Field" sample accounts for its slightly higher density and tensile strength than the "Standard". The differences in percent elongation and target thickness (weight) will be subsequently discussed.

During the course of this investigation it was learned that the production of Marlex 6001 (Standard) has been discontinued as of March 1974 and the producer has recommended to one molder that Marlex 5502 be used in lieu thereof.

In view of the foregoing, the need for new quality assurance requirements for material is quite apparent. It is also obvious that the developed material requirement should be correlatable with satisfactory field performance.

To reduce the heat effects of solar radiation on the target, consideration may be given to either painting the targets with Enamel, Lusterless, Quick Drying, Styrenated Alkyd type, Solar Heat Reflecting MIL-C-4606 or using the combination of heat reflecting pigments in this paint (Ref 5) as a substitute for the olive drab colorant pigments currently used in targets. If painting is done, then techniques for developing good adhesion to the target material must be developed.

Design Considerations

Although generally conforming with design requirements, it should be noted that the "Field" target is thinner and consequently weighs less than the "Standard" target.

Target thickness has an important bearing on hit response accuracy (Ref 1). Its importance to resistance to warpage is alluded to in Appendices C and D, but is not documented with evidence to establish the optimum thickness. The 80 mil thickness requirement was previously established as an optimum (Ref 1) when consideration was given for an attached three dimensional target and weight limitations of the training pop-up and recording device (M31A1 and 3C52) holders (Ref 4). Since heat effects are transmitted inward from the surface, it can be expected that a thicker polyethylene (poor conductor) target would maintain better rigidity over a longer period

of exposure to solar radiation than a thinner target. Therefore, when targets are used without attached three dimensional targets (Figures 1 to 3) consideration should be given to reoptimizing the thickness requirements upward for improved performance at elevated temperatures. Additional measures, such as straightening sides of the ribs to a maximum to provide greater stiffness and to straighten the curvature of the target holding device (reduce induced stresses) would help to alleviate the elevated temperature warpage problem.

Processing

The relations between basic molecular properties (density, melt index, average molecular weight) and the physical and other properties of polyethylene are not always simple and clear. Often, molecular structural features other than basic properties exert some influence on certain physical properties. Processing conditions may radically change the orientation (alignment) of the molecules in the resin and thus, too, affect some of its properties. For example, the difference in percent elongation of the "Standard" samples varies from 235 to 560% in the longitudinal direction and 195 to 500% in the transverse direction (Table 1). Differences of lesser magnitude are also observable for percent elongation of the "Field" samples in both directions. The largest difference in tensile strengths (3845 psi vs. 3985) was found in two specimens stamped from the longitudinal direction of the "Standard" sample. These anistropic effects are directly attributable to cold drawing or polymer crystallization under directional stresses induced by sheet extrusion and thermoforming operations. While anisotropic aspects of processing can never be entirely eliminated they can be minimized by the development of "meaningful" specification tests and requirements for the fabricated item.

When thermoplastics are processed the polymers are melted, shaped and cooled from the surface inwards. This can result, in unfavorable cases, in thermal stresses which may influence properties such as impact resistance, shrinkage, warpage etc. of the article. Freezing of the outer skin hinders the stress-free contraction of inner zones of the polymer during cooling. In semicrystalline polyethylene, stresses created by shrinking as the interior of the article cools inside a frozen skin are augmented by volume contraction effects arising when the inner zones, which cool more slowly, crystallize to a greater extent. The magnitude of thermal stresses developed depends on the elastic modulus of the frozen polymer, its thickness, its coefficient of linear thermal expansion, the specific volumes of crystallized and melted polymer, the initial melt temperature and the temperature to which the article is cooled. Although thermal stresses are not large in well made polyethylene articles, they can reach considerable magnitudes under some circumstances. Therefore, experiments were devised to determine:

a. The extent of warpage created in the "Field" target by elevated temperature exposure.

b. The means for its prevention.

c. The means for the straightening of warped targets and preventing the reoccurence of warpage in them at elevated temperatures.

An examination of Table 2 and Figures 6 and 7 will show how all objectives were met. By heating specimens to 260°F (slightly below the crystalline melting point of 276°F) locked-in thermal stresses, due to processing, were relieved without melting. Restraints, when imposed on the specimens, prevented warpage no matter how specimens were cooled. However, when restraints were removed and the specimens were reheated to 260°F, it was only the previously ice water quenched specimens which would show zero warpage (a new "plastic memory"). The previously air and oven cooled specimens retain the original "plastic memory" (warpage of 2.75 inches at 260°F and 1.25 inches at room temperature) due to its mechanical and thermal processing history.

CONCLUSIONS

- Current quality assurance provisions for material are inadequate for determining the "equivalency" of any other high density polyethylene to "Marlex 6001". Based on broader characterization, than currently required, the material used to fabricate the submitted "field" target is not "equal" to Marlex 6001.

- The selection of Marlex 6001 as the "Standard" is questionable because of its low heat distortion temperature at 66 psi (165-170°F) when compared to other possible candidate materials, such as polyhexamethylene (300-360°F), acetal (338°F) and polycarbonates (282-293°F).

- A thicker (80 mil) target with straighter ribs sides will provide increased resistance to deformation forces (wind, bullet impingement, clamps) at elevated temperatures.

- Targets which, due to faulty processing techniques, will or have warped at elevated temperatures can be simply treated to provide "warp proofness". In addition, simple test procedures and requirements can be developed to assure the procurement of targets which have been suitably processed.

RECOMMENDATIONS

1. Determine whether thicker (100-110 mil) targets, submitted by the target developer (Appendix H) to Forts Polk and Jackson for evaluation, have performed satisfactorily during the summer of 1974. If performance is satisfactory then targets of equivalent thickness and design should be fabricated from the substitute for Marlex 6001 (no longer produced) and evaluated in a like manner.

2. A selected number of on hand "Field" targets should be restrained from movement and heat treated at 260 ± 5°F for 1 hour and then quenched in ice water. Prior to removal of the restraints, the target material should be at ambient. The treated targets (80 mils thick) should be evaluated in a similar manner as in paragraph 1 above.

3. All evaluations in paragraphs 1 and 2 above shall be meticulously recorded. In addition, unfired upon (unexposed and exposed) targets, fully identified, shall be set aside for the development of "meaningful" specification tests and requirements for material and fabrication process.

4. If none of the evaluations performed in paragraphs 1 and 2 above yield satisfactory targets, then consideration should be given to the following in order of economic advantage:

a. Determine whether painting targets with Enamel, Solar Heat Reflecting, Olive Drab, MIL-C-46096 will reduce target temperature sufficiently to prevent warpage.

b. If treatment 4a is successful then determine if solar heat reflecting pigments used in the paint can successfully replace pigments used in the targets.

c. If feasible, determine whether straightening of the holding clamp will reduce warpage.

d. Redesign of ribbing (straightening of sides) to provide greater stiffness.

e. Selection and testing of other plastic materials.

REFERENCES

1. Terry, Robert B. Technical Report: NAVTRADEVCEN IH-78, March 1968, Naval Training Device Center, Orlando, Florida 32813, 46 pages.

2. Test and Evaluation Report, Contract N61339-1820, 29 August 1966.

3. Long, David T. Technical Report: NAVTRADEVCEN IH-188, December 1971, Polyethylene Silhouette Target Utilization, Naval Training Device Center, Orlando, Florida 32813, 10 pages.

4. Brieff, Philip; Raffo, John A. Technical Report: NAVTRADEVCEN 66-C-0077-1, Three-Dimensional Targets for the Pop-Up Devices M31A1 and 3C52.

5. CCL Report No. 188, 4 October 1965 "Development of an Olive Drab Solar Heat Reflecting and Low Visibility Enamel". M.H. Sandler. U. S. Army Coating and Chemical Laboratory, Aberdeen Proving Grounds, Maryland.

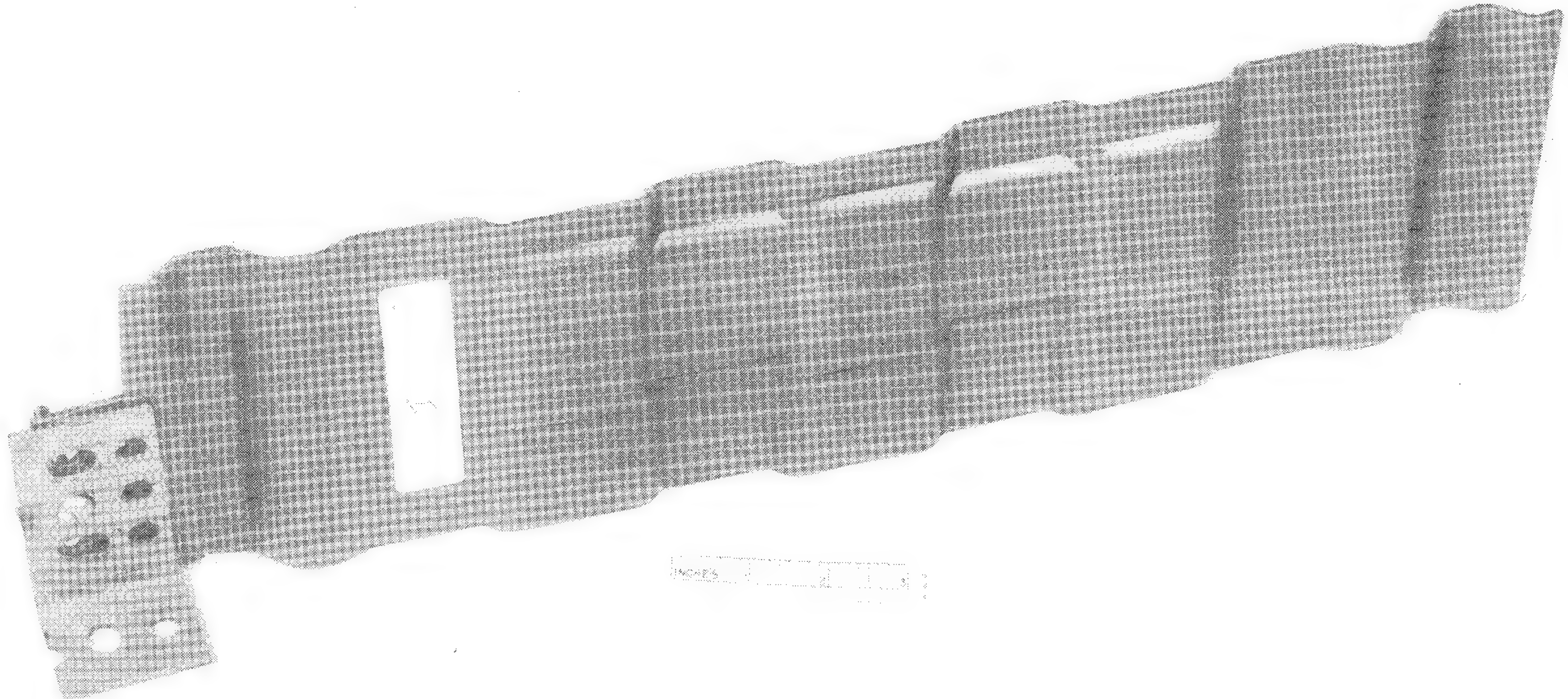
TABLE 1

TARGET MATERIAL PROPERTIES

	FIELD		STANDARD	
Markings	#12002898 (ink)		P/NS-E-77 RAI Research Corp Patent Pending (Molded)	
Flatness	Flat		Slightly warped	
Color	Green		Olive drab	
Holding Slots	2 vertical(at base)		None	
Weight, lbs.	1.861		2.434	
Thickness, inches	0.075 to 0.087		0.094 to 0.114	
Melting Range, °C	120 to 142		114 to 142	
Melting Point (crystalline) °C	135.5		135.5	
Freezing Point, °C	124		124	
Penetration Point, °C	130		130	
Melt Index, gms/10min. @ 190°C	0.207		0.206	
Intrinsic Viscosity(1)	1.00		1.41	
Tensile Strength, psi., 2" min.	1	2	1	2
Longitudinal Direction	4020	4010	3985	3845
Transverse	4250	4280	4000	3975
Elongation, %, 2" min.	1	2	1	2
Longitudinal Direction	700	675	560	235
Transverse	465	525	500	195
Density, gms/cc.	0.966		0.959	
Ash @ 600°C, %	1.42		0.68	
Polymer Identity	Polyethylene		Polyethylene	

(1) A measure of approximate average molecular weight ($\overline{M}w$)

$$\left[1.00 \sim 130{,}000\ \overline{M}w, \quad 1.45 \sim 400{,}000\ \overline{M}w\right]$$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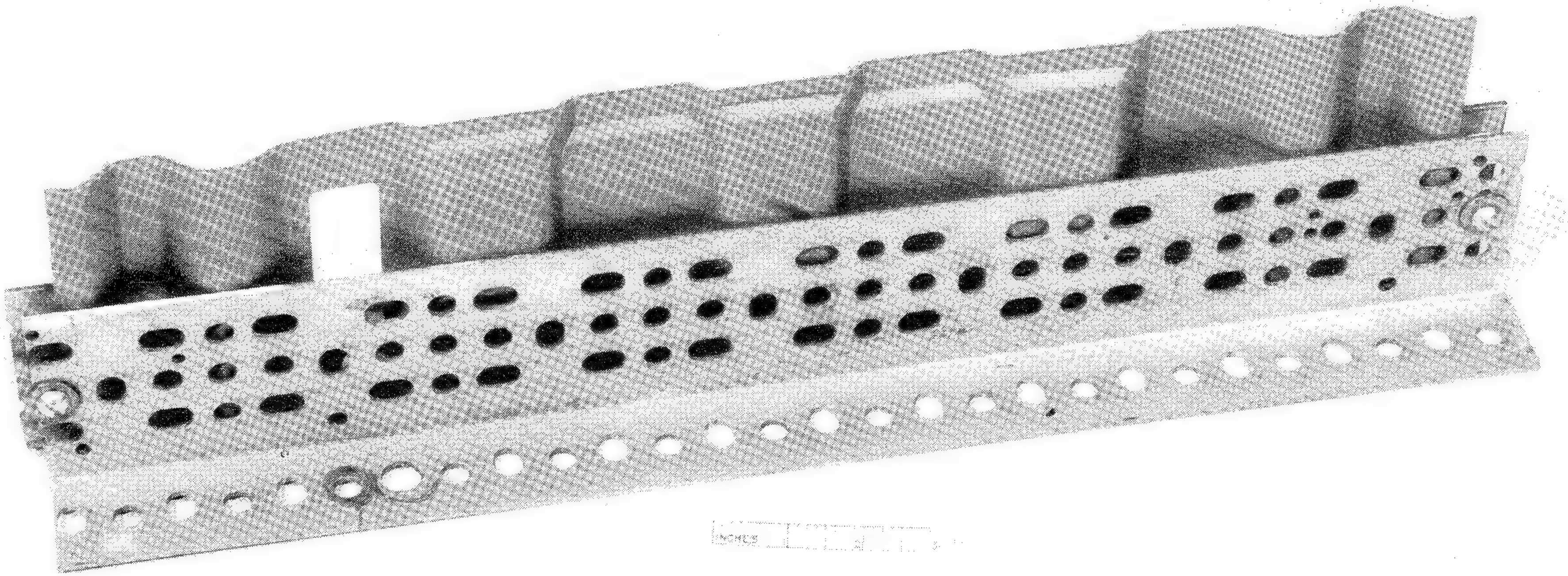


Fig 5 Restrained Movement
Warpage Test Fixture

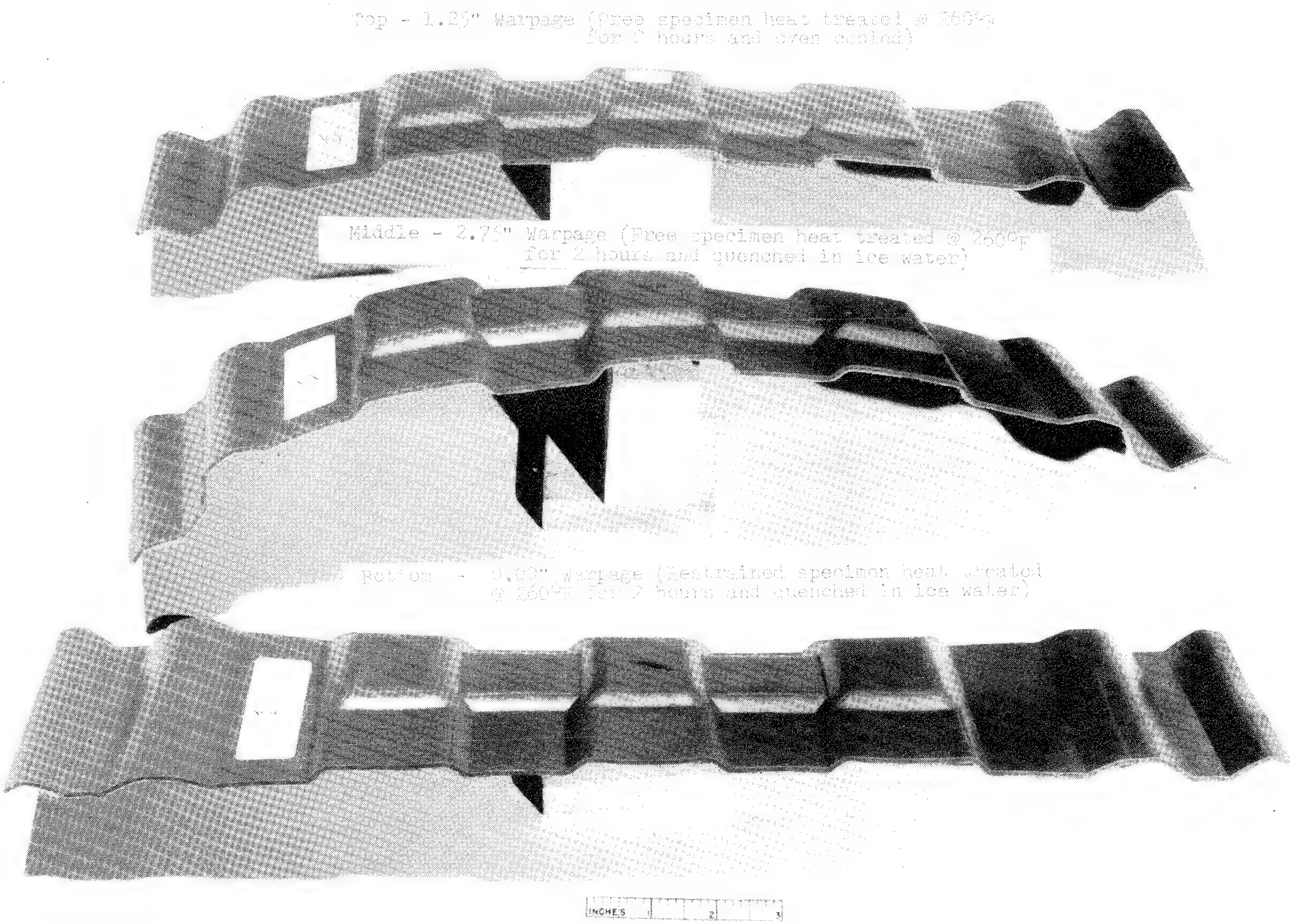
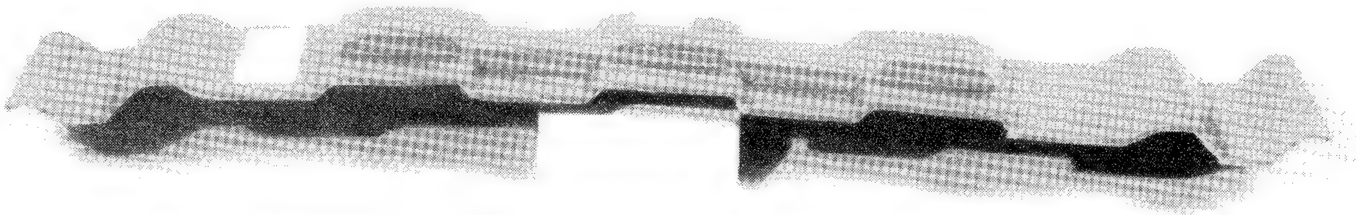
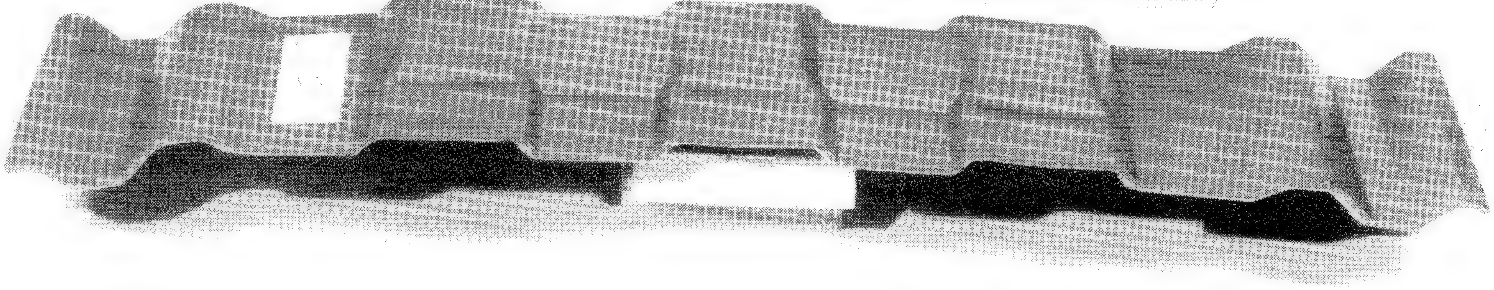


Fig 6 Extent of Warpage of Transverse Sections of the Field Target

Top - Initial Warpage of 1.25" is corrected
(see Table 2, specimen III for treatment details)



Middle - Initial Warpage of 2.75" is corrected
(see Table 2, Specimen II for treatment details)



Bottom - Original flat section was prevented from Warping
(See Table 2, Specimen I for treatment details)

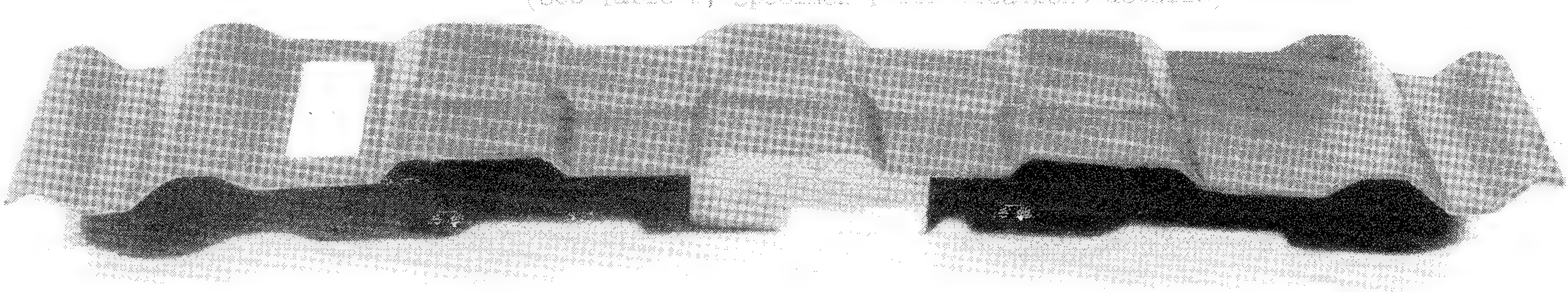
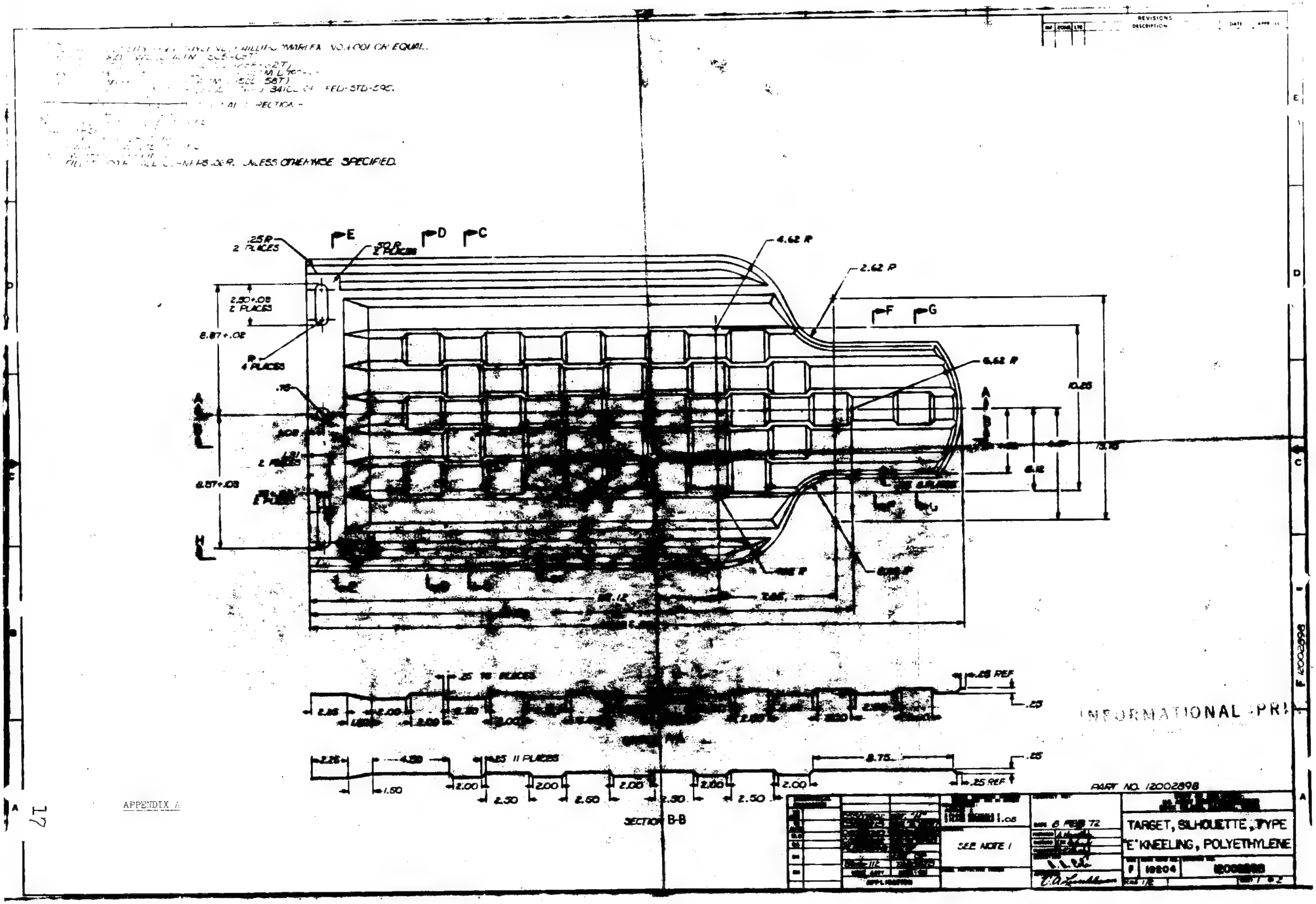


Fig 7 Prevention and Correction of Warpage of
Transverse Sections of the Field Target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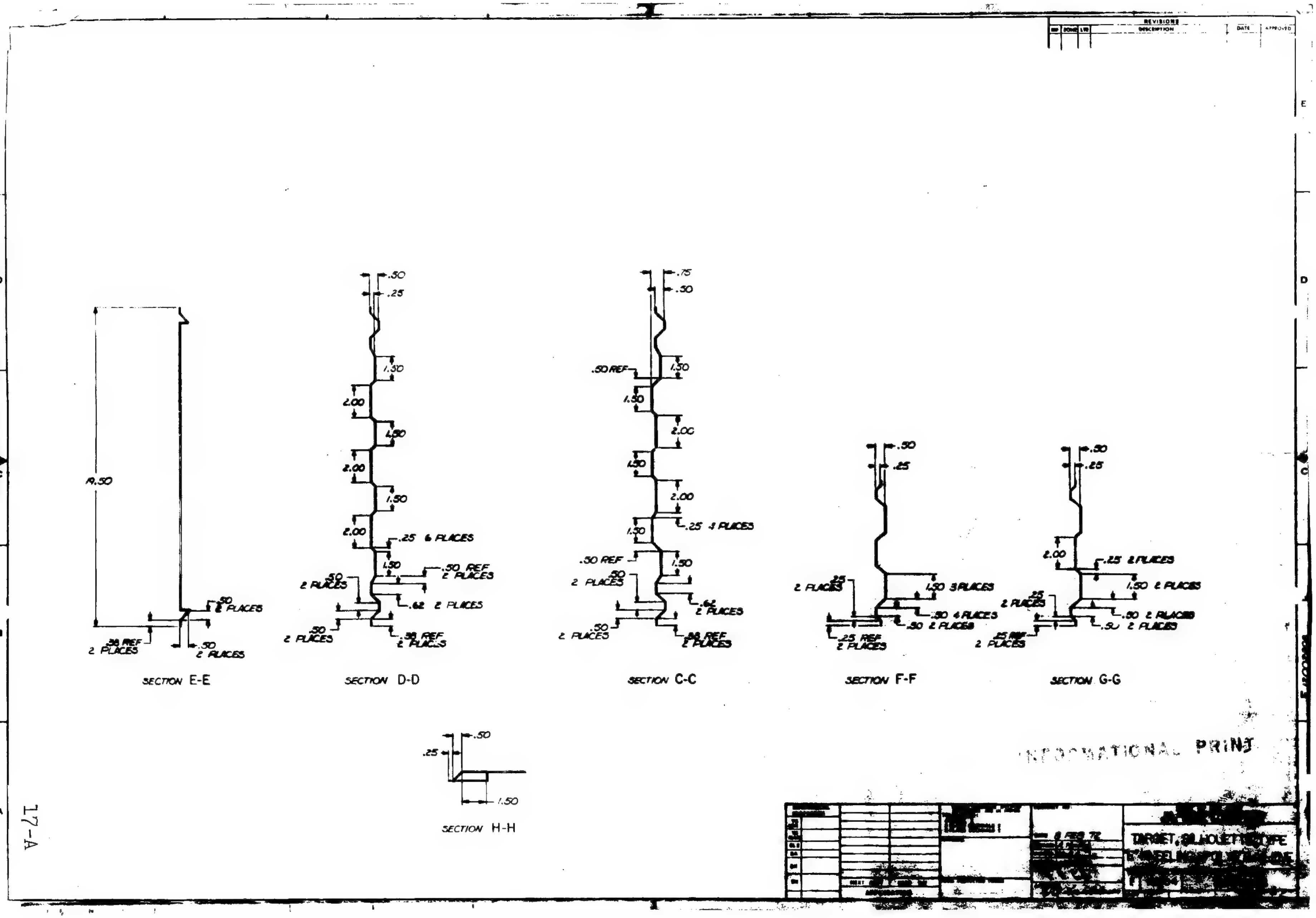
APPENDIX A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SECTION D-D
SECTION C-C
SECTION F-F
SECTION G-G
SECTION H-H
INFORMATIONAL PRINT

DEPARTMENT OF THE ARMY
ROCK ISLAND ARSENAL
ROCK ISLAND, ILLINOIS 61201

SARRI-LS-P

15 Oct 73

SUBJECT: Polyethylene Targets

Commander
Picatinny Arsenal
Plastic Technology Evaluation Center
ATTN: SARPA-FR-MD
Dover, New Jersey 07801

1. This Arsenal requests your technical assistance regarding the selection of a plastic material to overcome a problem that has developed with the subject target. The problem developed during the past spring and summer. Solar radiation (heat from direct sun light) causes the target material to soften and deform. The softening reduces the effectiveness of the automatic target mechanism to record projectile hits on the target. Further, the deformation of the target presents to the gunner a reduced silhouette.

2. It is most desirable to continue using a plastic material for the target, as the plastic tends to close the bullet holes after being hit. This permits a second bullet to pass thru approximately the same hole and record another hit. This also provides a longer usage life.

3. The current material is a high density polyethylene, designated as Phillips Petroleum Company's "MARLEX" No. 6001 or equal. See inclosed target drawing for details of material and configuration. If a material can be provided to overcome the heat problem and maintain its physical properties under cold conditions, it would be desirable to have a source for procurement. It is intended to fabricate sufficient targets of an improved material to perform evaluation under extreme climatic conditions.

4. If the foregoing request for technical assistance requires further explanation and/or if funding is required, please inform the above office. Contact is L.S. MacMillan, auto 793-4562.

FOR THE COMMANDER:

R. S. Henry

1 Incl
as

R. S. HENRY
Chief, Product Engineering Division

DEPARTMENT OF THE ARMY
ROCK ISLAND ARSENAL
ROCK ISLAND, ILLINOIS 61201

SARRI-LS-P

21 Nov 73

SUBJECT: Polyethylene Target

Commander
Picatinny Arsenal
Plastic Technology Evaluation Center
ATTN: SARPA-FR-MD, Mr. Eig
Dover, New Jersey 07801

1. Reference is made to:

a. SARRI-LS-P letter, dtd 15 Oct 73, to SARPA-FR-MD, subject as above.

b. Telecon, 9 Nov 73, between Mr. Merrill Eig, Picatinny Arsenal, and Mr. L.S. MacMillan, Rock Island Arsenal.

2. The referenced letter requested technical assistance regarding selection of a new material to overcome deformation of current material caused by solar heat absorption. The referenced telecon was to obtain further explanation of that request. This letter is written to elaborate on the problem and recommend approaches to be taken.

3. The following are estimated performance parameters for the plastic target:

a. Target installed on firing ranges will be exposed to climatic conditions for prolonged periods, estimated three month average.

b. Extreme temperatures range from $-40^{o}F$ to $+ 200^{o}F$ (estimated extreme temperature caused by heat absorption from the sun).

c. The average target life is 3000 projectile hits per target.

4. The objective of the referenced letter request is to provide a target to meet the preceding paragraph 3 requirements and overcome the problem stated in that letter. The following sequence of evaluations are recommended to cover all aspects of the problem:

SARRI-LS-P
SUBJECT: Polyethylene Target 21 Nov 73

a. In order to insure that the specified material is as required by the drawing, it is requested that an analysis of fielded target material be made. Samples taken from a fielded target are being sent under separate cover for this purpose.

b. Based on positive results of a. above (i.e., material is as required), research plastic materials to determine if a satisfactory replacement to meet performance requirements is available. This would be the most expedient and economical, as tooling is available to produce current configuration.

c. If the foregoing efforts fail to satisfy the objective, a program to develop an improved design using the best available material will be undertaken.

5. To elaborate further on the problem photographs are inclosed showing the subject targets installed on target mechanism in field use. Note that all targets are deformed to some degree. The targets as shown on mounts were usually stored in the down or horizontal position. However, interim improvement measures were taken by issuing the following instructions to the user:

a. Leave targets in the upright position when not in use.

b. Replace targets when initial bending is first noted. These targets will harden when removed from exposure to sun's rays and can be used later.

6. This Arsenal will continue to be available to provide further guidance, as stated in reference a. letter.

FOR THE COMMANDER:

R S Henry

Incl
6 Photographs

R. S. HENRY
Chief, Product Engineering Division

APPENDIX C

RAI Research Corporation 225 Marcus Boulevard Hauppauge, L.I., N.Y. 11787 516 273-0911 Telex: 96-7763

May 13, 1974

Mr. Leonard R. Weiner
Picatinny Arsenal
Material Engineering Lab
Building #183
Dover, New Jersey 07801

Dear Mr. Weiner:

We appreciate your consulting R A I regarding the warping problem of the waffle polyethylene targets, experienced by training bases under warm temperature conditions. During our meeting of May 6, 1974, we indicated that we had expressed our concern regarding this in that over the last several years targets which were purchased by Central Procurement were fabricated from thinner plastic sheet than were submitted by our company, both as the final product developed by our company and subsequent sales of the target by R A I to various bases throughout the U. S. (This problem was pointed out in our letter of May 26, 1968 to Naval Training Device Center and our letter of March 8, 1972 to Army Material Command. Copies of these letters were given to you for your reference.)

We are not herein proposing that the total solution to this problem is a heavier target, but certainly a thinner target than the one developed compounds the problem. Our suggestions as to the steps required to solve this problem will be outlined hereinafter, but excerpts from our letters heretofore referred to follow in order to further clarify these comments:

May 28, 1968 to NTDC

- "We pointed out that the bid contained no performance and quality assurance specifications which we believe essential to insure the effectiveness of this target. The purpose of this letter is to further expand on the necessity for performance and quality assurance specifications. We would suggest that independent verification be made with the Naval Training Device Center personnel involved in the evaluation of these targets.

May 13, 1974

The target as specified in the subject bid did not consider several aspects of prime importance:

1. Rock Island Arsenal Laboratory, under project number 1-A-0-13001-A-039 (September 5, 1962) did an extensive study entitled, "The Development of Fiber-board Targets for the M31A1 Trainfire Mechanism." The abstract of this report is enclosed for your examination. You will note that it concluded the statement that "the final criterion for evaluation must be the firing test."

Based upon the report mentioned above, cardboard targets have been procured by a performance test conducted at a suitable range. At a minimum, polyethylene targets should be required to meet applicable portions of that specification, and prospective suppliers be required to qualify their targets before they are considered a source of supply. No subsequent work on plastic targets has contradicted the Rock Island Laboratory findings on the need for performance testing.

2. Another point of consideration is that Note #6 of drawing #361000B60001 says of thickness that "Targets shall be formed from sheet stock which is .080" + 5" in thickness. This does not really describe what the finished thickness of the target should be. It would therefore be possible to stamp press targets of a 75 gauge sheet, resulting in a far less effective target but which would still comply with the bid. The improved performance of the heavier gauge has been repeatedly demonstrated by R A I and Naval Training Device Center evaluation reports. R A I Research, being aware of this, has always supplied the Army Marine Corps and Naval Training Device Center with targets having a mean thickness of greater than .080" to insure the necessary field performance.

3. The forming of the sheet after extrusion, as provided for in the bid, must be done so as to insure a maximum wall thickness throughout the waffle section. The normal manufacture of this type of part, as may be seen in most commercially available molded parts, would be a short cycle forming operation with no consideration to wall thickness. This type of manufacture would result in a thinner wall, especially in the most critical center section which would make the target far less effective. The waffle thickness is important for the following reasons:

a) To insure vibration transmission to the microswitch to indicate hit/kill response especially critical with the M16 rifle.

b) Have sufficient material surrounding the bullet hole to initiate the flow characteristic required to reduce the size of the hole so that a subsequent bullet in the same spot will still respond. Also, the volume of material on contact would resist shattering. Shattering would obviously make the target unresponsive.

c) To resist the vertical whiplash and horizontal deformation force after 1,500 hits, the thickness of the horizontal and vertical ribs is essential to provide the strength required to minimize this force.

In responding to the above referenced bid, R A I, estimated its cost on the required quality control, the slower forming cycle which assured a heavier gauge in the waffle, and the heavier gauge sheet. There are numerous additional performance and quality assurance specifications which can be added to the bid. The main point is that it is essential that they be included for the best interests of the Government and its training program."

<u>March 8, 1972 to AMC</u>

"In determining the thickness of the target, detailed evaluations were conducted with sheet high density polyethylene materials ranging from 60 to 93 mils. The results of these tests were that the thicker targets showed significant improvements in response accuracy and hit capability with all other performance characteristics about the same.

The final evaluation targets manufactured by R A I were 90 mils in thickness and the initial performance data was satisfactory. At the conclusion of the evaluation R A I, as you know, sold targets to numerous Army bases before they were available through NTDC. All of these targets including our current inventory as shown in the attached brochure, were 90 mils. However, government specifications assigned to the target were 80 mils ± 5 mils and several large volume central procurements were made with that thickness requirement.

In our recent visits to the various bases introducing them to our target training equipment, we have found that the targets in the field are approximately 75 mils and response accuracy and warping, especially in warm weather, have been a problem. As you know, both of these factors are quite critical in training effectiveness and, in fact, were two of the major reasons for initiating a target development program to begin with.

In connection with the foregoing and our background in target development and plastics technology, we recommend that an evaluation program be conducted with a thicker gauge target so that improved performance characteristics could be clearly demonstrated. Specifically, we propose manufacturing an evaluation quantity of 2,500 "E" targets of 100 mil thickness. We are confident that these thicker targets will result in substantially improved response accuracy and considerably reduce buckling.

In projecting ahead, if this thicker target were centrally purchased in large volume, the difference in cost, if any, would be slightly more than the price presently paid by NTDC in their volume procurements of this past year. The difference would be limited to the additional resin cost, all other manufacturing procedures remaining the same. However, the cost effectiveness and performance would be greatly enhanced. (I would like to note that beyond 110 mils, manufacturing, especially vacuum forming cycle time, would change the cost picture beyond the additional resin required.)

We believe the approval of this request will give the government the true worth of the initial target development program. We respectfully request that you consider the above proposal as we sincerely believe this improved target is in the best interests of the Government."

No doubt, based on the foregoing, R A I alerted the military to the warping problem currently of concern and the suggestions therein are most valid.

We would propose the following:

1. Thickness specifications for current purchases be changed to 90 mil sheet stock and detailed quality assurances and performance specifications be generated thereon which would include:

   a) Quality assurance of the base material utilizing laboratory tests for gel permeation, molecular distribution, tensile and stiffness tests, etc.

   b) Thickness specifications - Initial specifications of minimum sheet stock, minimum thickness of the side wall of the waffle structure (this side wall can vary depending on the cycle time in the vacuum forming equipment).

   c) Additional specification including weight of target, flatness tolerances and color, etc.

   d) Performance specification to the extent they can practicably be managed. Please note R A I performance specification attached which was part of our target brochure.

2. Conduct a comparative evaluation of 90 mil and 100 mil targets specifically directed towards eliminating the current problem. Our opinion, as evidenced by work conducted by R A I under our initial development contract, is that the 100 mil target will prove far more effective regarding hit/kill response and would have less warping problems. We had indicated to you that R A I, at its own expense, manufactured 110 mil targets, 500 of which were sent to Fort Polk for evaluation. While the results of the Fort Polk evaluation will certainly be indicative, a larger scale test, under technical evaluation procedures would be more meaningful. We had initially proposed a test quantity of 2,500 each 90 and 110 mil targets under the direction of a technical agency such as Picatinny Arsenal and Range personnel.

3. Further development work should be considered for an improved target based on stability improved hit/kill response accuracy and increased hit quantity capability. In this regard R A I has had considerable experience in field requirements for targets, initially having developed the polyethylene target and thereafter gaining substantial first-hand knowledge while visiting numerous bases throughout the country. As you know, R A I sells to the U. S. military target training equipment that, along with the M31A1, utilize these very same targets. The point being that our training management personnel believe that other materials, now currently available together with a redesign of the target structure would greatly improve the targets overall capability and cost effectiveness.

I am hopeful that these comments assist you in your mission. R A I is prepared to provide to the U. S. Government its technical services and target expertise wherever meaningful.

Very truly yours,

R A I RESEARCH CORPORATION

S. J. Arditti
President

rad

POLYETHYLENE TARGETS

Performance Data Sheet

90 mill Target, Nominal Waffle and Rib Structure Thickness not less than 80 mills

Performance Specifications

Firing Test	Target mounted at a distance of 75 yards in M31A1 train-fire device or equivalent.
Response Accuracy	With 30 caliber Spitzer round, 40 visually verified hits, device activates a minimum of 38 times.
	M-16 rifle - 60 visually verified hits, device activates a minimum of 55 times.
Residual Hole Size	30 caliber (.30 inches) Spitzer type bullet fired perpendicular to target surface should leave a hole not larger than .22 inches.
Target Endurance Test	2000 visually verified hits with a response accuracy of 90% minimum.
Environmental Test	After being holed by 100 - 30 caliber rounds, target should be submerged in water for 24 hours. Upon removal target should be subjected to 1900 visually verified hits with a response accuracy of 90% minimum.
Shatterproof	Target weight after being holed by 200 rounds of 30 caliber ammunition should be reduced by no more than 0.5% of original weight.

March 8, 1972

Mr. Frank Domingoes
AMC-ATTN
U. S. Army Material Command
Washington, D. C. 20310

Re: Proposal for Evaluation of 110 Mil Polyethylene "E" Type Target - Waffle Structure

Dear Mr. Domingoes:

As you know, R A I Research Corporation developed the Polyethylene "E" Type Waffle Target currently in extensive use by the U. S. military forces. During the initial stages of this development R A I evaluated many materials, structures and thicknesses to determine the best target considering cost effectiveness, response accuracy and hit capability.

In determining the thickness of the target, detailed evaluations were conducted with sheet high density polyethylene materials ranging from 60 to 93 mils. The results of these tests were that the thicker targets showed significant improvements in response accuracy and hit capability with all other performance characteristics about the same.

The final evaluation targets manufactured by R A I were 90 mils in thickness and the initial performance data was satisfactory. At the conclusion of the evaluation R A I, as you know, sold targets to numerous Army bases before they were available through NTDC. All of these targets including our current inventory as shown in the attached brochure, were 90 mils. However, government specifications assigned to the target were 80 mils $\pm$ 5 mils and several large volume central procurements were made with that thickness requirement.

In our recent visits to the various bases introducing them to our target training equipment, we have found that the targets in the field are approximately 75 mils and response accuracy and warping, especially in warm weather, have been a problem. As you know, both of these factors are quite critical in training effectiveness and, in fact, were two of the major reasons for initiating a target development program to begin with.

In connection with the foregoing and our background in target development and plastics technology, we recommend that an evaluation program be conducted with a thicker gauge target so that improved performance characteristics could be clearly demonstrated. Specifically, we propose manufacturing an evaluation quantity of 2,500 "E" targets of 110 mil thickness. These targets would be the exact same structure as the current procurement except that we would notch out the bottom of the targets so that they would fit into both the M31A1 and DART mechanisms. We are confident that these thicker targets will result in substantially improved response accuracy and considerably reduce buckling.

The proposed initial evaluation cost for 2,500 targets including modification and special handling is $9,700, with delivery four weeks after contract approval. Subsequent small quantities for further evaluation would be available at $2.60 each.

In projecting ahead, if this thicker target were centrally purchased in large volume, the difference in cost, if any, would be slightly more than the price presently paid by NTDC in their volume procurements of this past year. The difference would be limited to the additional resin cost, all other manufacturing procedures remaining the same. However, the cost effectiveness and performance would be greatly enhanced. (I would like to note that beyond 110 mils, manufacturing, especially vacuum forming cycle time, would change the cost picture beyond the additional resin required.)

We believe the approval of this request will give the government the true worth of the initial target development program. We respectfully request that you consider the above proposal as we sincerely believe this improved target is in the best interests of the Government.

Very truly yours,

R A I RESEARCH CORPORATION

S. J. Arditti
President

SJA/cd

May 28, 1968

Mr. S. E. Smith
Contract Negotiator
Naval Training Device Center
Orlando, Florida 32813

Reference: IFB N61339-68-B-0076
RAI-P103

Dear Mr. Smith:

This letter follows our letter of May 24, 1968, to Mr. John W. Pease, at which time RAI formally indicated to Naval Training Device Center our contention of a proprietary position on the target being procured by Naval Training Device Center under the above referenced bid. We are hopeful this will be considered by Naval Training Device Center and/or Army patent people at the earliest possible time.

In addition, we pointed out that the bid contained no performance and quality assurance specifications which we believe essential to insure the effectiveness of this target. The purpose of this letter is to further expand on the necessity for performance and quality assurance specifications. We would suggest that independent verification be made with the Naval Training Device Center personnel involved in the evaluation of these targets.

The target as specified in the subject bid did not consider several aspects of prime importance:

1. Rock Island Arsenal Laboratory, under project number 1-A-0-13001-A-039 (September 5, 1963) did an extensive study entitled, "The Development of Fiberboard Targets for the M31A1 Trainfire Mechanism." The abstract of this report

is enclosed for your examination. You will note that it concluded with the statement that "the final criterion for evaluation must be the firing test."

Based upon the report mentioned above, cardboard targets have been procured by a performance test conducted at a suitable range. At a minimum, polyethylene targets should be required to meet applicable portions of that specification, and prospective suppliers be required to qualify their targets before they are considered a source of supply. No subsequent work on plastic targets has contradicted the Rock Island Laboratory findings on the need for performance testing.

2. Another point of consideration is that Note #8 of drawing #861000B60001 says of thickness that "Targets shall be formed from sheet stock which is .080" + 5" in thickness." This does not really describe what the finished thickness of the target should be. It would therefore be possible to stamp press targets of a 75 gauge sheet, resulting in a far less effective target but which would still comply with the bid. The improved performance of the heavier gauge has been repeatedly demonstrated by RAI and Naval Training Device Center evaluation reports. RAI Research, being aware of this, has always supplied the Army Marine Corps and Naval Training Device Center with targets having a mean thickness of greater than .080" to insure the necessary field performance.

3. The forming of the sheet after extrusion, as provided for in the bid, must be done so as to insure a maximum wall thickness throughout the waffle section. The normal manufacture of this type of part, as may be seen in most commercially available molded parts, would be a short cycle forming operation with no consideration to wall thickness. This type of manufacture would result in a thinner wall, especially in the most critical center section which would make the target far less effective. The waffle thickness is important for the following reasons:

a) To insure vibration transmission to the microswitch to indicate hit/kill response especially critical with the M16 rifle.

b) Have sufficient material surrounding the bullet hole to initiate the flow characteristic required to reduce the size of the hole so that a subsequent bullet in the same spot will still respond. Also, the volume of material on contact would resist shattering. Shattering would obviously make the target unresponsive.

c) To resist the vertical whiplash and horizontal deformation force after 1,500 hits, the thickness of the horizontal and vertical ribs is essential to provide the strength required to minimize this force.

In responding to the above referenced bid, RAI estimated its cost on the required quality control, the slower forming cycle which assures a heavier gauge in the waffle, and the heavier gauge sheet. There are numerous additional performance and quality assurance specifications which can be added to the bid. The main point is that it is essential that they be included for the best interests of the Government and its training program.

Very truly yours,

RAI RESEARCH CORPORATION

S. J. Arditti
President

SJA:dh
Enclosure
(Letter in duplicate)

cc: Mr. John W. Pease
Naval Training Device Center

APPENDIX D

PHILLIPS PETROLEUM COMPANY
FAIRFIELD, NEW JERSEY 07006
20 NEW DUTCH LANE

CHEMICAL DEPARTMENT
Plastics Division

May 24, 1974

FILE: ES-53-74

SUBJECT: Polyethylene Targets

Mr. Leonard R. Weiner
Materials Engineering Laboratory
Building 183
Picatinny Arsenal
Dover, NJ 07801

Dear Mr. Weiner:

You had requested our assistance in the warpage problem being experienced on polyethylene rifle targets. We would like to comment as follows:

1. Our evaluation indicated the targets appeared to have been formed from Marlex® EHM 6001. We based this on the density and melt index of the sheet.

2. The target design can be improved to resist warpage by making the ribs more pronounced. The sides of the ribs should be straightened to the maximum. This will result in greater part stiffness. In addition, we recommend the use of 187 mil sheet. The 80 mil sheet appeared to be too flimsey, as indicated by the apparent wind warpage shown in picture #2.

3. To help utilize the targets on hand you might consider the use of supporting wood frames. In addition, we recommend that existing mounting plates be straightened where necessary. The target in picture #3 appeared to be mounted on a noticeably bent mounting plate.

Enclosed are the pictures and the part drawings you had loaned me. I also have the targets if you should want them returned to you.

If you have any questions, please call.

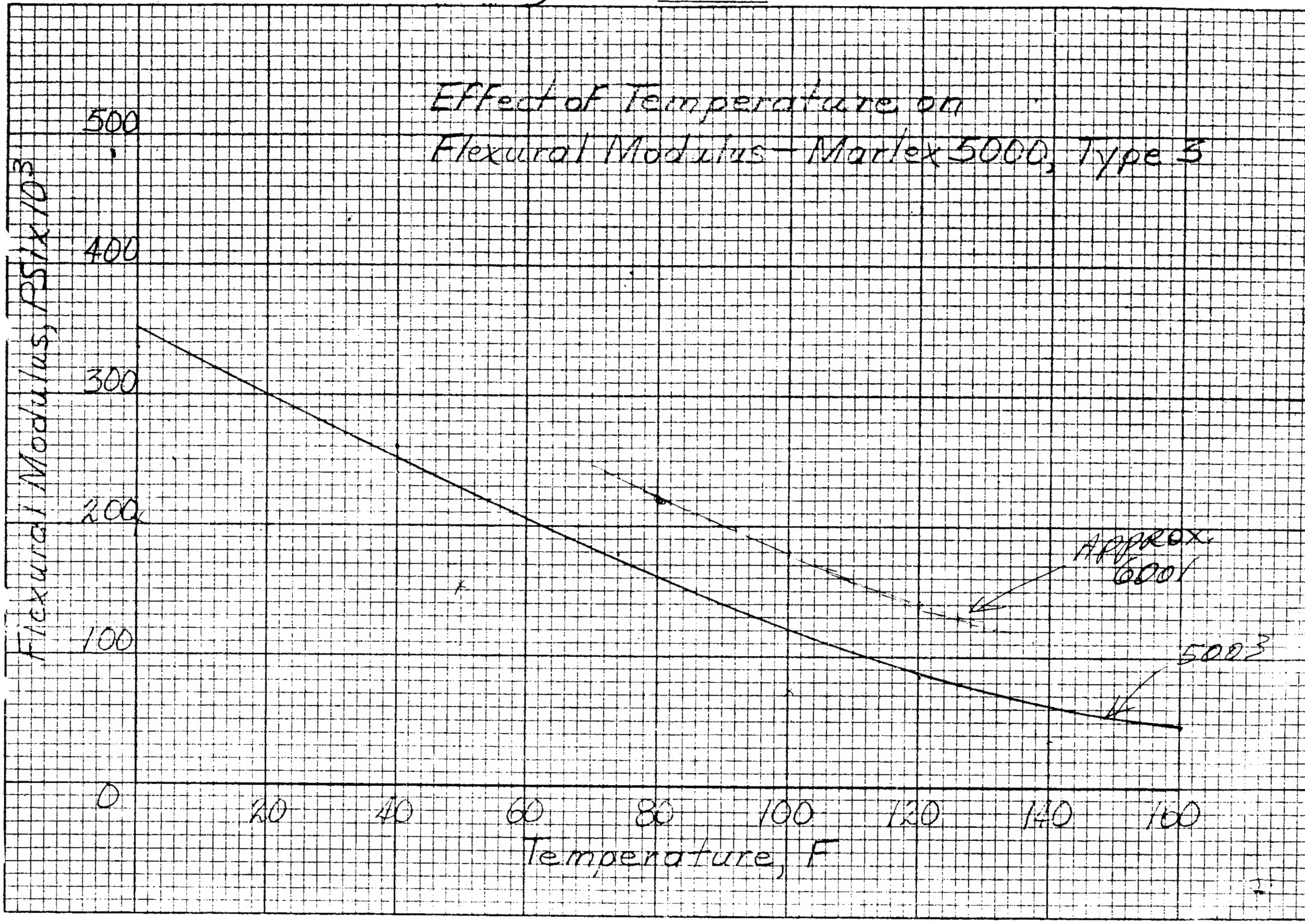
Very truly yours,

Eli Solop

Eli Solop
Tech. Serv. Engineer

ES:sas
cc: H. B. Walker
Enclosure

APPENDIX E



Effect of Temperature on
Flexural Modulus—Marlex 5000, Type 3
Flexural Modulus, PSIx10³
500
400
300
200
100
0
20
40
60
80
100
120
140
160
Temperature, F
Approx. 6001
5003

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